UNITED STATES DISTRICT COURT WESTERN DISTRICT OF WASHINGTON

Penny D. Goudelock,

Appellant,

v.

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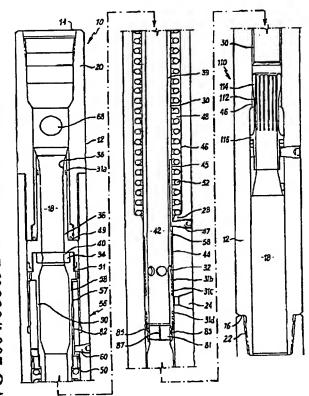
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(54) Title: DOWNHOLE TOOL



(57) Abstract: A downhole tool which can perform a task in a well bore, such as circulating fluid radially from the tool. The function is selectively performed by virtue of a sleeve moving within a central bore of the tool. Movement of the sleeve is effected by dropping a ball through a ball seaf on the sleeve. Movement of the sleeve is controlled by an index sleeve such that the tool can be cycled back to the first operating position by dropping identical balls through the sleeve. Embodiments are described wherein the balls are deformable, the seat is deformable and the seat provides a helical channel through which the ball passes.

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Downhole Tool

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2	
3	The present invention relates to the selective operation
4	of downhole tools as used in the oil and gas industry and
5	in particular, though not exclusively, to a re-settable
6	circulation tool operated by a drop ball mechanism.
7	
8	While many downhole tools operate continuously through a
9	well bore e.g. scrapers and brushes as disclosed in US
10	6,227,291, it is more desirable to provide a tool which
11	performs a function only when it has reached a preferred
12	location within a well bore. An example of such a tool
13	would be a circulation tool as disclosed in WO 02/061236.
14	The tool provides a cleaning action on the walls of the
15	casing or lining of the well bore. The cleaning action
16	may be required after the casing has been brushed or
17	scraped and thus the tool is designed to be selectively
18	actuated in the well bore. Such tools provide the
19	advantage of allowing an operator to mount a number of
20	tools on a single work string and operate them
21	individually on a single trip in to the well bore. This
22	saves significant time in making the well operational.

Tools which are selectively actuable in a well bore 1 commonly operate by having an element which can be moved 2 relative to the tool when in the well bore. In the 3 circulation tool of WO 02/061236, the element is a sleeve 4 located in the cylindrical body of the tool. When run in 5 the well, the sleeve is held in a first position by one 6 7 or more shear screws. To actuate the tool, a drop ball is released from the surface of the well through the work 8 string. On reaching the sleeve, the ball blocks the flow 9 of fluid through the tool and consequently pressure 10 11 builds up until the shear screws shear and the sleeve is forced downwards. The movement of the sleeve is then 12 stopped when a lower ledge of the sleeve contacts a 13 shoulder on the internal surface of the tool body. 14 15 16 Such tools have a number of disadvantages. The tools are 17 generally limited to one actuable movement. If two 18 sleeves are incorporated to overcome this, the shear screws of the second sleeve can operate prematurely under 19 the shock created to shear the shear screws of the first 20 21 sleeve. Additionally, the reduced bore diameter of the 22 lower part also effects the flow rate achievable through 23 the tool. 24 25 One tool which has been developed to operate repeatedly 26 is that disclosed in US 4,889,199. This tool comprises a tubular body having a radial port into which is located a 27 28 sleeve having a matching radial port. The sleeve is slidably mounted and its action controlled from a 29 30 deformable drop ball biasing the sleeve against a spring. Initially the spring biases the sleeve to a closed 31 32 position in which the ports are misaligned. The drop ball 33 causes the sleeve to move to a position where the ports

align due to a build up of pressure behind the ball, and fluid is discharged radially through the ports. A small steel ball is then dropped into the tool which seals the

4 radial ports and the consequential pressure build up

5 extrudes the deformable ball through the ball seat. The

6 steel ball will drop with the deformable ball and both

7 are retained in a ball catcher at the base of the tool.

8 When the balls drop together the spring biases the sleeve

9 back to the closed position and the tool can be operated

10 repeatedly.

11

12 A disadvantage of this tool is that it requires both a

13 deformable ball and a smaller metal ball to operate. Care

14 must then be taken to ensure the balls are dropped in the

15 correct order. The smaller metal ball must lodge in the

16 second, radial, outlet in order to stop flow and thus the

17 tool is restricted to having a single radial port. This

18 limits the amount of cleaning which can be performed.

19

20 It is an object of the present invention to provide a

21 downhole tool which obviates or mitigates at least some

22 of the disadvantages of the prior art.

23

24 It is a further object of at least one embodiment of the

25 present invention to provide a circulation tool which is

26 re-settable and operated by similar drop balls.

27

28 It is a further object of at least one embodiment of the

29 present invention to provide an actuation mechanism to

30 move a sleeve within a downhole tool.

31

32 According to a first aspect of the present invention

there is provided a downhole tool for selectively

performing a task in a well bore, the tool comprising a 1 substantially cylindrical body having a central bore 2 running axially therethrough, a sleeve located within the 3 bore, the sleeve including a ball seat, a plurality of 4 balls, each ball having substantially similar dimensions 5 and each ball arresting a majority of fluid flow through 6 the bore when located in the ball seat, mechanical 7 8 biasing means located between the sleeve and the body to 9 bias the sleeve in a first direction, and functional means on the body to perform a task in the well bore, the 10 11 functional means being operable on relative movement of 12 the sleeve, wherein the functional means has at least a 13 first and a second operating position, each change in 14 position being effected by passing a said ball through 15 the sleeve in a reverse direction, and wherein the said changes form a cyclic pattern such that the functional 16 17 means can be cycled back to the first operating position. 18 19 The tool can therefore be operated a number of times while located in a well bore. Further all operations are 20 21 controlled by dropping identical balls through the tool and thus there is no co-ordination required in dropping 22 23 the balls. 24 It will be appreciated that while the term ball has been 25 used, this represents any shaped projectile which can be 26 dropped into the fluid flow, travel to and seat in the 27 28 ball seat, and further travel through the ball seat. Such projectiles may be plugs, bombs darts or the like. 29 30 31 Preferably the ball seat releasably retains each ball. Preferably the ball seat is a ledge or shoulder located 32 on an inner surface of the sleeve means. The ball 33

therefore rests on the shoulder until sufficient pressure

2 builds up to force the ball past the shoulder.

3

4

4 In a first embodiment, the balls are deformable. In this

5 way each ball can be released by passing through the ball

6 seat when sufficient pressure is applied to it.

7

8 When a ball is dropped in the body, the ball will locate

9 in the ball seat. The ball will block the fluid path

10 through the tool and consequently pressure will build up

11 on the ball by fluid prevented from travelling through

12 the body. This pressure will be sufficient to move the

13 ball and sleeve together against the mechanical bias and

14 force the sleeve in the reverse direction. When the limit

15 of the bias is reached, increased pressure will cause the

16 ball to deform and pass through the ball seat. On release

17 of the ball, pressure drops and the sleeve is biased in

18 the first direction. The movement of the sleeve actuates

19 the tool and moves the functional means to an operating

20 position.

21

22 In a second embodiment, the ball seat may be a deformable

23 ball seat. Preferably the deformable ball seat includes a

24 part conical surface having an aperture therethrough.

25 Advantageously the aperture has a diameter less than a

26 diameter of the ball. Preferably the deformable ball seat

27 is made of a flexible material, so that at a

28 predetermined pressure it flexes to release the ball.

29 Advantageously the deformable ball seat is made of a

30 metal so that the seat is not prone to wear during use.

31

32 The deformable ball seat may comprise a spring such as a

33 disc spring. Preferably the deformable ball seat has

6 sufficient elasticity such that it returns to its 1 original dimensions once a ball has passed therethrough. 2 Optionally the deformable ball seat may be of a layered 3 structure. Preferably the layered structure comprises a 4 5 plurality of disc springs. 6 7 Throughout this specification the term deformable refers to the ability of an element to change shape within its 8 9 own volume as it deforms. This is in contrast to 10 expandable wherein the element must get bigger i.e. 11 extend beyond its outer diameter. 12 Preferably the balls of the second embodiment are 13 spherical. More preferably the balls are of a non-pliable 14 material and thus cannot deform. Advantageously the balls 15 16 are made of steel. 17 In the second embodiment, when a ball is dropped in the 18 19 body, the ball will locate in the deformable ball seat. 20 The ball will block the fluid path through the tool and 21 consequently pressure will build up on the ball by fluid 22 being impeded in travelling through the body. This pressure will be sufficient to move the ball and sleeve 23 24 together against the mechanical bias and force the sleeve 25 in the reverse direction. When the limit of the bias is 26 reached, increased pressure will cause the seat to expand 27 against the pressure of the ball. The ball will pass 28 through the expanded ball seat. On release of the ball, 29 pressure drops and the sleeve is biased in the first 30 direction. The movement of the sleeve actuates the tool

and moves the functional means to an operating position.

31

1 In a third embodiment the ball seat may comprise a

2 helical channel on an inner surface of the sleeve.

3

4 Preferably the helical channel has curved walls. This

5 will prevent damage to a ball passing through the

6 channel. Preferably also the ball is sized to provide a

7 restricted fluid by-pass around the ball when in the

8 channel. This ensures a positive pressure is maintained

9 behind the ball and prevents chattering of the ball in

10 the channel.

11

12 The helical channel may be considered as a screw thread.

13 Thus the channel has a left hand thread so that a ball

14 travels in the opposite direction to the rotation of the

15 tool on a work string. Preferably a pitch of the thread

16 is greater than or equal to a diameter of each ball.

17

18 Preferably the balls are spherical. More preferably the

19 balls are of a non-pliable material and thus cannot

20 deform. Advantageously the balls are made of steel.

21

22 Preferably also the sleeve includes a conical surface at

23 an entrance to the channel. This funnels the ball into

24 the channel and ensures it travels into the helical path.

25

26 For this embodiment, when a ball is dropped in the body,

27 fluid will drive the ball into the channel and into the

28 helical path. As the ball is sized for the channel it

29 will block the majority of the fluid path through the

30 tool and consequently pressure will build up behind the

31 ball. This pressure will be sufficient to move the ball

32 and sleeve together against the spring and force the

33 sleeve in the reverse direction. On release of the ball

ı from the channel the sleeve is biased in the first direction. The movement of the sleeve actuates the tool 2 and moves the functional means to an operating position. 3 4 Preferably the mechanical biasing means is a strong 5 6 spring. The spring may be helical, conical or the like. A 7 strong spring will prevent the sleeve moving in the reverse direction by fluid flow in the central bore. 8 Preferably also the mechanical biasing means is located 9 in a chamber created between the sleeve and the body. 10 Advantageously the chamber includes an exhaust port such 11 12 that fluid can enter and be dispelled from the chamber by relative movement of the sleeve and the body. This 13 provides a damping effect which prevents shock movements 14 in the tool. 15 16 17 Preferably a choke ring is located around the sleeve. Preferably the ring has an extended portion in the 18 longitudinal plane to provide an extended surface area to 19 20 match the outer surface of the sleeve for fluid to flow therebetween. The shape of the ring, assists in 21 22 providing a damping action as the sleeve moves in the reverse direction. Fluid which has to pass the sleeve as 23 24 it moves downwards is forced to take a route having a 25 restricted flow path in the first direction. 26 damping helps prevent the mechanical bias e.g. a spring 27 or other parts, from 'bouncing' into a location which 28 could result in the functional means being moved to an 29 unwanted operating position. 30 31 Preferably the tool further comprises engagement means to

32 control relative movement between the sleeve and the

1 body. Preferably also the mechanical bias biases the

2 sleeve against the engagement means.

3

4 Preferably said engagement means comprises at least one

- 5 index pin located in a profiled groove. Preferably the at
- 6 least one index pin is located on the body and the
- 7 profiled groove is located on an outer surface of the
- 8 sleeve. In this way, an index sleeve is produced with the
- 9 groove determining the relative position of the sleeve to
- 10 the body. Advantageously the groove extends
- 11 circumferentially around the sleeve, this enables the
- 12 tool to be continuously cycled through a number of
- 13 operating positions.

14

- 15 Preferably the tool further includes a ball non-return
- 16 element. Preferably the element is a split ring located
- 17 in the bore below the sleeve. Advantageously the ring is
- 18 located at the base of a ramp on an inner surface of the
- 19 body. Preferably the ramp is arranged such that if a
- 20 ball pushes against the ring in the first direction, the
- 21 ring will travel up the ramp and thereby reduce in
- 22 diameter as edges of the split are forced together. This
- 23 reduction in diameter will prevent a ball from travelling
- 24 in a first direction back up through the tool.

- 26 Advantageously the tool includes a ball arrester.
- 27 Preferably the arrester is located below the ball seat.
- 28 The inner surface of the sleeve may be shaped to provide
- 29 the ball arrester. Preferably the ball arrester
- 30 comprises a plurality of surfaces transversely arranged
- 31 to the central bore. Preferably the surfaces provide a
- 32 convoluted path which a ball must take through the
- 33 sleeve. Preferably the path is sized such that fluid may

1 pass around the ball during its passage. In this way, the

- 2 momentum of the ball as it passes through the seat is
- 3 dissipated before the ball reaches any further ball seats
- 4 in the tool or in the work string to which it is
- 5 attached. This prevents the ball 'exploding' through
- 6 restrictions in the bore and allows restrictions, such as
- 7 further ball seats, to be mounted relatively closely to
- 8 the ball seat.

9

- 10 Preferably the tool further comprises a second ball seat.
- 11 The second ball seat is located below the sleeve and
- 12 allows the central bore to be blocked in any operating
- 13 position, if desired.

14

- 15 The second ball seat may comprise a collet including a
- 16 plurality of fingers directed in the first direction.
- 17 Preferably the collet is closed and the fingers are
- 18 brought together by the action of the sleeve locating
- 19 between the fingers and the body. In this way, when the
- 20 sleeve is moved in the reverse direction the passage
- 21 through the central bore is restricted as the collet
- 22 closes. A ball is then arrested on the collet. When the
- 23 sleeve moves in the first direction by a predetermined
- 24 distance the collet opens and the ball is released to
- 25 travel through the tool.

- 27 Alternatively the second ball seat may comprise a trapped
- 28 'C' ring, or split ring. Again movement of the sleeve
- 29 between the ring and the body will cause the ring to be
- 30 compressed wherein its diameter reduces. A ball will
- 31 therefore be prevented from passing through the bore and
- 32 be impeded at the ring. Movement of the sleeve in the
- 33 first direction by a predetermined direction will free

the ring and, by expansion, the ball can pass through the

2 now increased aperture.

3

4 Advantageously the second ball seat is a shuttle

5 arrangement. The shuttle arrangement comprises a

6 plurality of part cylindrical sleeves. Preferably the

7 sleeves combine to form a complete sleeve which is

8 located in the body. Preferably at least a first part

9 cylindrical sleeve is connected to the sleeve, such that

10 it moves with the sleeve. Preferably at least a second

11 part cylindrical sleeve is attached to the body and is

12 prevented from longitudinal movement in the bore.

13 Preferably the part cylindrical sleeves overlap in the

14 bore at all times, such that movement of the sleeve

15 brings them into sliding engagement. More preferably,

16 when the sleeves are brought together, the internal bore

17 created has a diameter smaller than the diameter of the

18 balls, but that one or more balls can pass between a part

19 cylindrical sleeve and an inner surface of the body.

20 Preferably a free end of each part cylindrical sleeve

21 includes a funnel portion. More preferably the funnel

22 reduces the diameter of the part cylindrical sleeve from

23 that of substantially the body to that of the inner bore.

24 The funnel may be stepped. In this way, only when then

25 the funnels of each part cylindrical sleeve are aligned

26 can balls pass through the second ball seat.

27

28 Preferably the tool is a circulation tool. The

29 functional means may comprise at least one first port

30 arranged substantially transversely to the central bore

31 through the body, and at least one second port arranged

32 transversely to the central bore through the sleeve, such

33 that alignment of the ports causes fluid to be discharged

1 from the central bore and wherein alignment of the ports

2 is controlled by relative movement of the sleeve.

3

4 More preferably there are a plurality of said first and

5 said second ports. Advantageously there are three or more

6 said first and said second ports. Preferably also said

7 first and said second ports are spaced equidistantly

8 around the body and sleeve respectively.

9

10 Preferably also the tool includes ball collecting means.

11 The ball collecting means may be an element located in

12 the casing means to prevent passage of the ball through

13 the tool, but allowing passage of fluid through the tool.

14

15 According to a second aspect of the present invention

16 there is provided a method of circulating fluid in a

17 borehole, the method comprising the steps:

18

19 (a) inserting in a work string a tool comprising a

tubular body including a plurality of first radial

21 outlet ports in which is located a sleeve including

- 22 a plurality of second radial outlets;
- 23 (b) running the work string and tool into a borehole,
- 24 with the sleeve in a first position relative to the
- 25 body wherein the first and second radial outlets are
- 26 arranged in a first operating position;
- 27 (c) dropping a ball into the work string such that the
- 28 ball lands on the sleeve and forces the sleeve into
- 29 a second position relative to the casing wherein the
- 30 first and second radial outlets are arranged in an
- intermediate operating position and fluid flow is
- 32 restricted by the ball;

1 (d) increasing pressure behind the ball to cause the
2 ball to pass through the sleeve, the releasing
3 pressure allowing the sleeve to move to a third
4 position relative to the body wherein the first and
5 second radial outlets are arranged in a second
6 operating position; and wherein the ports are
7 aligned in either of the operating positions and
8 misaligned in the other operating position.

9

In this way, the tool can be run into the borehole with the ports in an open or closed configuration. The intermediate position is a position where the tool is primed between he first and second operating positions.

14

15 Preferably the method further includes the steps of:

16 17

18

19

20

21

22

23

(e) dropping a second ball, substantially similar to the first ball, into the work string such that the second ball lands on the sleeve and forces the sleeve into the second position relative to the body wherein the first and second radial outlets are arranged in the intermediate operating position and fluid flow is restricted by the second ball; and

24 (f) increasing pressure behind the second ball to cause
25 the second ball to pass through the sleeve, the
26 releasing pressure allowing the sleeve to move to
27 the first position relative to the body wherein the
28 first and second radial outlets are arranged in the
29 first operating position.

30

31 With the sleeve and body back in the first position, the 32 steps (c) to (f) can be repeated. In this way the tool 33 can operate in a cyclic manner.

1 Preferably the method includes the step of moving the

2 sleeve against a mechanical bias.

3

4 Preferably the method includes the step of controlling

5 movement of the sleeve relative to the body by use of an

6 index sleeve.

7

8 Preferably the method includes the step of decelerating

9 the ball as it passes from the sleeve to dissipate the

10 pressure.

11

12 Preferably the method includes the step of stopping the

13 ball in a second ball seat after it has passed through

14 the sleeve. Preferably this step further includes the

15 step of preventing fluid flow through the work string

16 while directing it through the radial ports.

17

18 Preferably also the method includes the step of catching

19 the dropped balls in the work string.

20

21 According to a third aspect there is provided a ball

22 arrester for dissipating momentum of a ball after it has

23 passed through a ball seat, the arrester comprising a

24 substantially cylindrical body in which is located a non-

25 linear pathway through which the ball is guided.

26

27 Preferably the pathway comprises a plurality of surfaces

28 transversely arranged to a central bore. Preferably each

29 transverse path has a curved ramp extending therefrom to

30 the next transverse surface. Preferably also each

31 transverse surface extends across a portion of the bore

32 so that the ball can pass between the surfaces.

33 Advantageously adjacent surfaces are off-set so that the

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ball is forced to run along each surface before 1 travelling to the next surface. Preferably the surfaces 2 provide a convoluted path which a ball must take through 3 the body. Preferably the path is sized such that fluid may pass around the ball during its passage. In this way, 5 the kinetic energy of the ball as it passes through the б seat is dissipated before the ball reaches any further ball seats in a tool or in the work string to which it is 8 This prevents a ball 'exploding' through 9 attached. restrictions in the bore and allows restrictions, such as 10 further deformable ball seats, to be mounted relatively 11 closely to the ball seat. 12 13 According to a fourth aspect of the present invention 14 there is provided a ball seat for a downhole tool, the 15 ball seat comprising a plurality of part cylindrical 16 sleeves which can shuttle with respect to each other, 17 longitudinally in the tool, wherein a ball can only pass 18 through the seat when the sleeves are located at their 19 longitudinal extent. 20 21 Preferably the sleeves combine to form a complete sleeve 22 which is located in a cylindrical bore of the tool. 23 Preferably at least a first part cylindrical sleeve is 24 moveable within the tool. Preferably at least a second 25 part cylindrical sleeve is attached to the tool and is 26 prevented from longitudinal movement in the bore. 27 Preferably the part cylindrical sleeves overlap in the 28 bore at all times, such that movement of the first brings 29 them into sliding engagement by a shuttle motion. More 30 preferably, when the sleeves are brought together, the 31 internal bore created has a diameter smaller than the 32 diameter of a ball directed at the seat, but that a ball 33

1 can pass between a part cylindrical sleeve and an inner

- 2 surface of the tool. Preferably a free end of each part
- 3 cylindrical sleeve includes a funnel portion. More
- 4 preferably the funnel reduces the diameter of the part
- 5 cylindrical sleeve from that of substantially the body to
- 6 that of the inner bore. The funnel may be stepped. In
- 7 this way, only when the funnels of each part cylindrical
- 8 sleeve are aligned can balls pass through the ball seat.

9

- 10 According to a fifth aspect of the present invention
- 11 there is provided an actuation mechanism for a downhole
- 12 tool, the mechanism comprising a substantially
- 13 cylindrical body having a central bore running axially
- 14 therethrough, a sleeve located within the bore, the
- 15 sleeve including an deformable ball seat,
- 16 mechanical biasing means located between the sleeve and
- 17 the body to bias the sleeve in a first direction and a
- 18 ball, wherein the deformable ball seat releasably retains
- 19 the ball to prevent fluid flow through the sleeve and
- 20 cause the sleeve to move in the reverse direction
- 21 relative to the body and wherein on release of the ball
- 22 the seat returns to its original dimensions.

23

- 24 Preferably the mechanical bias is a strong spring. The
- 25 spring may be helical, conical or the like. A strong
- 26 spring will prevent the sleeve moving in the reverse
- 27 direction by fluid flow in the central bore.

- 29 Preferably the deformable ball seat includes a part
- 30 conical surface having an aperture therethrough.
- 31 Advantageously the aperture has a diameter less than a
- 32 diameter of the ball. Preferably the ball seat is made of
- 33 a flexible or elastic material, so that at a